Final report

Low-Dose Low-Energy SIMOX for Fully-Depleted Silicon-on-Insulator (SOI)

Phase I

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13. ABSTRACT (Maximum 200 words)

This Phase I program examined formation of low dose low-energy SIMOX utilizing the extraction voltage of 65 keV. The dose of 2E17 was found to be within the low dose process window at 65 keV. Samples of high structural and electricalquality were obtained with this dose. The intrinsic breakdown field of 4-6 MV/cm, silicon defect density on the order of 1E5/cm2, surface microroughness less than 2A were measured in these samples. The feasibility of the ultra-thin layer SIMOX with the silicon thickness below 90 nm on top of 50 nm thick BOX was demonstrated in high beam current Ibis1000 implanter. Promising material characteristics and significant cost reduction on the side of the equipment and material encourage to further investigate this approach to the formation of the low-dose low-energy SIMOX for fully-depleted Silicon-on-Insulator (SOI).

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SUMMARY

Advantages of fully-depleted SOI technology are prominent in sub-quarter micron circuits scale. These circuits require application of very thin and uniform SOI layers. For large volume supply, the cost of fabrication needs to complement high quality material performance. In SIMOX technology, these requirements implicate the need for the development of the cost efficient low oxygen dose process.

The program "Low-Dose Low-Energy SIMOX for Fully Depleted Silicon-on-Insulator (SOI)" funded by the DARPA / US ARMY contract #DAAH01-97-C-R282 examined the new process approach using lower than usual energy of implantation. Experiments were performed in Ibis 1000 implanter utilizing only its extraction voltage of 65 keV. The experiments covered the entire dose range of SIMOX formation at 65 keV. The dose of $2x10^5$ O^+/cm^2 was found to be within the low dose process window at 65 keV. With this dose samples of high structural and electrical quality were obtained exhibiting the intrinsic breakdown field of 4-6 MV/cm, silicon defect density on the order of 1E5 cm-2 and silicon surface microroughness less than 2A. The feasibility of the ultra-thin layer SIMOX with silicon thickness below 90nm on top of 50 nm thick BOX was demonstrated in high beam current implanter.

As shown in the Phase I of this program, at 65 keV , the oxygen dose producing continuous buried oxide (BOX) layer is ~2 times lower than in high energy SIMOX process. Lower oxygen dose implicates immediate cost reduction. Furthermore, tailoring of the layer thickness during the implantation and annealing offers an opportunity of cost reduction by elimination of thinning steps. Competitive material characteristics of the low-dose low-energy SIMOX compared to the low-dose high-energy SIMOX encourage to continue investigations and developments of this material.

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1.0 INTRODUCTION

Advantages of fully-depleted SOI technology are prominent in sub-quarter micron circuits scale [1-5]. These circuits require application of very thin and uniform SOI layers. For large volume supply, the cost of fabrication needs to complement high quality material performance. In SIMOX technology, these requirements implicate the need for the development of the cost efficient low oxygen dose process[6].

At the present time SIMOX wafers with thin silicon layer suitable for fully-depleted applications are produced by thinning the top silicon layer of the standard dose or low dose high-energy SIMOX. The silicon layer in the annealed wafers is 180 - 360 nm thick. Thinning process is performed by sacrificial oxidations at a temperature in the range 900°C - 1350°C depending upon the starting thickness of the top silicon layer. Low temperature oxidation processes require extended times or multiple sacrificial oxidations to thin the layer to the desired thickness and introduce the risk of defect generation. Oxidations performed at the temperatures higher than 1150°C, induce Internal Thermal Oxidation (ITOX), a process resulting in a growth of an internal oxide at the silicon/buried oxide interface and improving the integrity of the BOX[7-11]. Simultaneously with the improvement of the BOX integrity, a reduced short range surface and interface microroughness are achieved. Although improvements of the material characteristics and their reproducibility by ITOX process are significant, yet the results are not fully satisfactory[12].

The phase I of the program " Low-Dose Low-Energy SIMOX for Fully Depleted Silicon-on-Insulator (SOI)" sponsored by the DARPA/US Army Contract #DAAH01-97-C-R282 was designed to examine the dose conditions for the formation of the continuous buried oxide layer implanted at 65 keV. The implantation processes were performed in high current Ibis1000 oxygen implanter utilizing its 65 kV extraction voltage. Implanter hardware was modified and special parts were fabricated to improve the oxygen beam conditions for low energy implant at 65 keV and to achieve high beam current. Versatile characterization methods employed to evaluate the properties of the experimental material have shown very promising structural and electrical characteristics. Overview of the Phase I work and its results is presented in the following sections.

2.0 REVIEW OF THE PHASE I PROJECT

The technical objectives of the Phase I of this program were to investigate novel process conditions and material characteristics of the next generation of thin film SIMOX obtained by implantation of low oxygen doses at energy below 100 keV. The extraction voltage of the high current Ibis1000 implanter was utilized to implant oxygen at 65 keV.

2.1 MATERIAL FABRICATION.

The starting substrates were Cz, <100> oriented, p-type, 10 - 20 Ohmcm, 150 mm silicon wafers, supplemented with four high resistivity ~1000 Ohmcm FZ wafers. Matrix of oxygen doses was implanted at 65 keV. The silicon substrate temperature was 500°C

during the implantation and the beam current was ~40 mA. Prior to the implantation of the experimental matrix, the low energy oxygen implantation process at 65 keV has been developed in Ibis 1000 implanter. Implanter hardware was modified (including fabrication of special parts) to achieve proper oxygen beam conditions and high beam current.

The experimental wafers were implanted at 65 keV with the following oxygen doses: $1.5x10^{17}$, $2.0x10^{17}$, $2.5x10^{17}$, $3.0x10^{17}$, $3.5x10^{17}$, $4.0x10^{17}$, $4.5x10^{17}$, $5.0x10^{17}$, and $7.0x10^{17}$ O^+/cm^2. These dose increments covered the entire range of SIMOX doses at 65 keV, from the low end to the equivalent of the full dose SIMOX. The annealing was performed in two groups. One group of wafers was annealed for 4 hours at 1350 °C in Ar(<1%O_2). The thickness of thermal oxide grown in this process was 88.5 nm. The second group of wafers was annealed with the deposited TEOS cap (to preserve the silicon thickness) for 6 hours at 1350 °C in Ar (5%O_2). Previously, these process conditions were found adequate to anneal capped low dose SIMOX wafers implanted at energies higher than 100 keV (comparable structural and electrical characteristics of low dose SIMOX annealed with and without cap were achieved).

The control group was implanted at 200 keV with the dose $4.1x10^{17}$ O^+cm^2 and annealed for 4 hours at 1350 °C in Ar(<1%O_2) and then oxidized at the same temperature for 7 hours in 30%O_2 ambient.

2.2 CHARACTERIZATION METHODS.

Various characterization methods were employed to examine the characteristics of the wafers from this experiment. The TXRF spectra was measured on the surface of the unannealed wafers to assure proper impurity levels after ion implantation. The contamination level during the anneal was controlled with the in-line chemical analysis by ICPMS and AAS, and routinely executed at Ibis manufacturing environment SPC methods. Layer thickness and composition were measured with spectroscopic ellipsometer (SE). Microstructure of the annealed samples was examined by the transmission electron microscopy (TEM) and Rutherford Backscattering Spectrometry (RBS). Impurity concentration profiles were measured with SIMS. Defect density in silicon layer was examined using enhanced Secco etch technique and optical microscopy. Surface and silicon/buried oxide interface topography was characterized with atomic force microscopy (AFM). The integrity of the buried oxide was tested using copper sulfate technique.

In addition to the above structural characterization methods, current-voltage characteristics were examined at Naval Research Laboratory.

2.3 RESULTS

Experiments performed during the Phase I of this program covered wide range of process conditions and revealed promising characteristics of SIMOX implanted with high beam current at low energy. These results will be shown and discussed in the following sections.

2.3.1 Structural Characteristics of the Low-dose Low-energy SIMOX BOX.

Microstructure of samples implanted at 65 keV was examined with spectroscopic ellipsometry. Two measurements were performed. In the first measurement, spectra of the annealed SOI structure was measured, and silicon and buried oxide layer thicknesses were determined. The second measurement was performed after stripping the silicon layer off in hot KOH. This measurement allowed to determine thickness and composition of the BOX with higher accuracy. The Bruggeman Effective Media Approximation method used in the SE, models the composition of the BOX as a mixture a stoichiometric SiO_2 and certain concentration of excess silicon. Thermal oxides and high quality, free of silicon inclusions buried oxides exhibit near 0% concentration of excess silicon. Higher concentrations of excess silicon relate to the presence of silicon inclusions in the BOX. In this experiment, the best structural composition was observed in samples implanted with the doses $2.0\text{x}10^{17}O^+/cm^2$ and $2.5\text{x}10^{17}O^+/cm^2$ and annealed with thermal oxide. Other samples exhibited significantly higher concentration of excess silicon indicating greater density of silicon inclusions. The magnitude of the concentration of excess silicon in the BOX detected with this method was slightly higher in the wafers annealed with the TEOS cap than in the wafers annealed with thermal oxide. The deposited oxide preserved approximately 10 nm of the silicon layer unless disturbed by the implant nonuniformity. The summary of the SE data is shown in Table I.

Table I . Summary of spectroscopic ellipsometry measurements of the 65 keV samples.

dose	**anneal with thermal oxide**			**anneal with TEOS cap**		
x 10^{17}	silicon thickness	BOX thickness	Si conc. in the BOX	silicon thickness	BOX thickness	Si conc. in the BOX
O^+/cm^2	nm	nm	%	nm	nm	%
1.5	99.8	61.0	32.00			
2.0	97.1	49.1	0.58	110.6	52.1	0.00
2.5	89.5	57.2	0.59	97.8	57.7	0.03
3.0	67.1	73.3	12.70	81.2	69.4	14.80
3.5	68.8	64.2	27.00	68.3	79.9	29.80
4.0	47.5	115.5	25.70	62.2	104.4	28.27
4.5				52.8	128.7	21.70
5.0	42.4	128.8	22.20	46.5	143.0	15.40
7.0	12.1	169.9	4.70	33.2	144.6	9.50

The TEM analyses has shown the highest quality microstructure in sample implanted with $2.0\text{x}10^{17}O^+/cm^2$ and annealed with thermal cap. Figure 1 shows the TEM cross section of this sample exhibiting free of silicon inclusions buried oxide with flat and smooth interfaces. Silicon dislocations are not observed. This sample has approximately 97 nm thick silicon layer on top of 50 nm thick BOX. The corresponding sample annealed with the TEOS cap has 110 nm thick silicon layer and similar thickness of the BOX. The TEM micrograph revealed presence of silicon inclusions in the BOX of the

sample implanted with the same dose but annealed with the TEOS cap. This effect indicates the need for more effort in the development of the annealing process with TEOS cap. In fact, the silicon inclusions were observed in all samples annealed with the TEOS capping layer. The experience gained in other Ibis' internal projects and externally funded programs has shown that increasing partial pressure of oxygen in the annealing ambient from <1% to 5% allows to obtain continuous thin BOX implanted at energy higher than 100 keV[13]. Also, earlier published work on low-dose low-energy SIMOX from the Surrey University has shown continuous buried oxide after anneals with the cap[14]. It is possible, however, that the ultra-thin layer process has higher sensitivity to the implanted dose or to the concentration of oxygen in the ambient than we have expected, and requires specific optimization effort. It needs to be noticed that for fully-depleted applications in small geometry circuits, 50 nm thick silicon layer or even thinner silicon layers are required[15]. This range of thickness can be achieved with thermal oxide grown during the anneal. The optimized anneal with the TEOS cap could be applicable in low-energy SIMOX equivalent of the full dose high-energy SIMOX and also would be very valuable for better process flexibility.

Evolution of the low-energy BOX microstructure with the increasing dose of oxygen was observed to be similar as in high energy SIMOX[16], and is illustrated in Figure 2. If the oxygen dose is too low, only isolated oxide precipitates are observed (a). Oxide precipitates coalesce into the continuous layer when the optimum dose is reached, and the anneal is satisfactory (b). Further increase of the dose results in the formation of thicker buried oxide with increasing density of silicon inclusions (c-e). When the dose is high enough, the microstructure typical of full dose high energy SIMOX implantation develops (f). The micrograph shown in this picture reveals presence of silicon islands near the bottom interface, similarly to the full dose SIMOX. Some smaller size silicon inclusions can be observed near the top interface indicating that the optimum process conditions haven't been yet achieved.

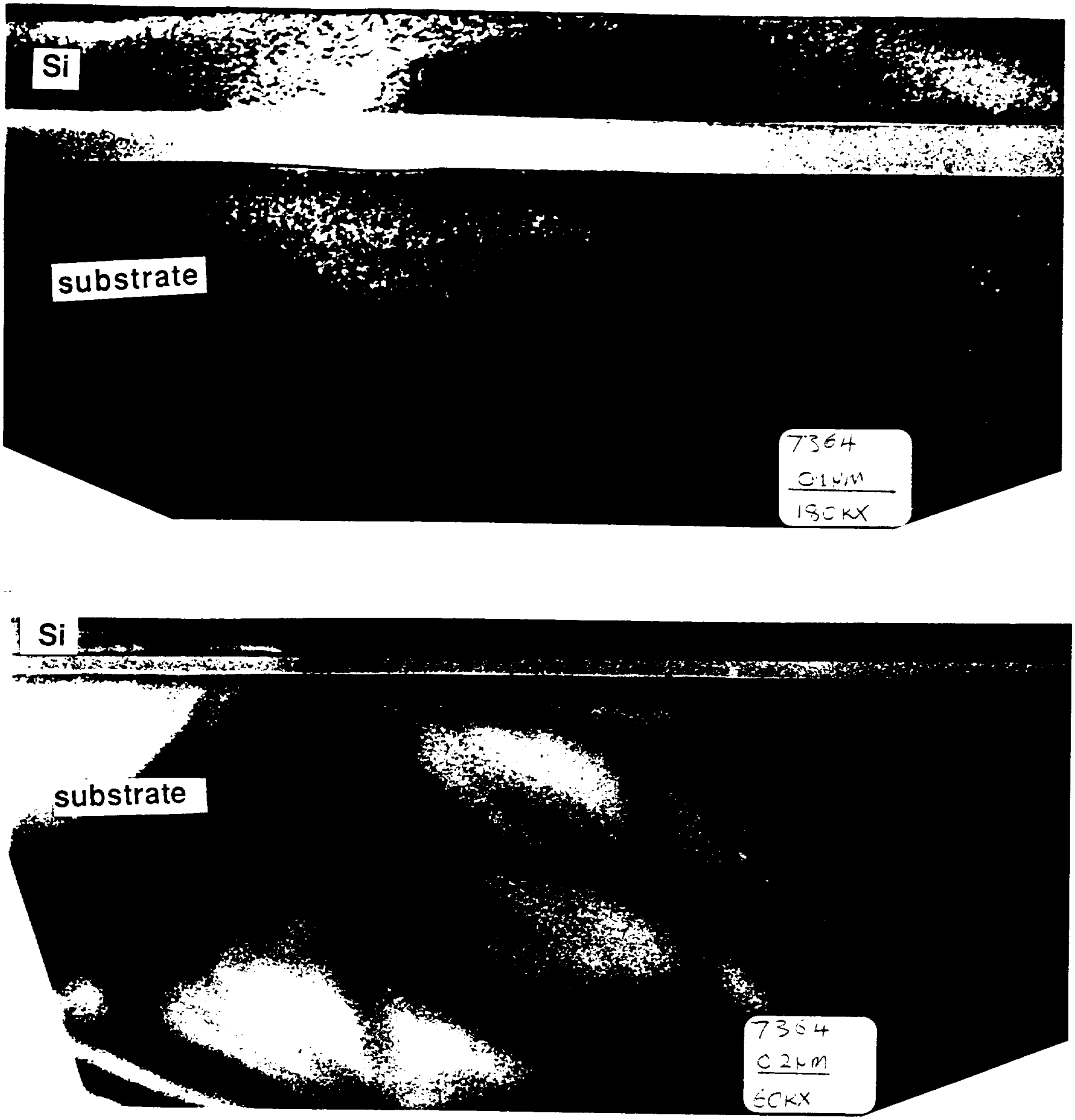
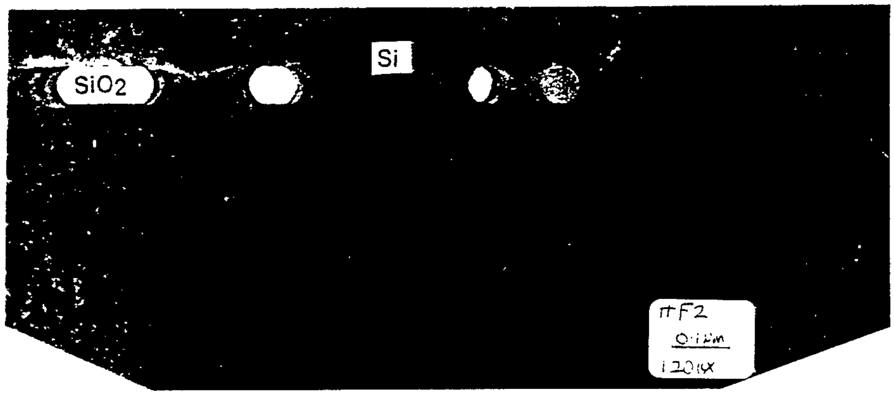


Figure 1. TEM cross section images of the sample implanted with the dose $2.0x10^{17} O^{+}/cm^{2}$ at 65 keV and annealed at 1350 °C for 4 hours in Ar(<1% O_2).

(a)



(b)

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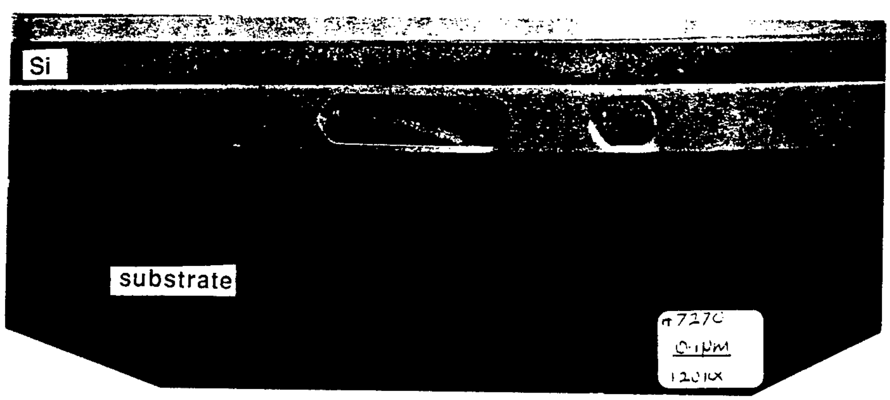
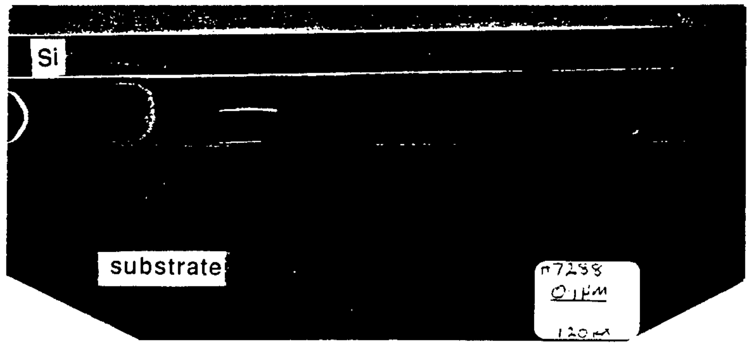


Figure 2. TEM cross section of samples implanted at 65 keV with the doses $1.5x10^{17}O^{+}/cm^{2}$ (a), $2.0x10^{17}O^{+}/cm^{2}$ (b), $3.5x10^{17}O^{+}/cm^{2}$ (c), $4.0x10^{17}O^{+}/cm^{2}$ (d) and $4.5x10^{17}O^{+}/cm^{2}$(e) and $7.0x10^{17}O^{+}/cm^{2}$ (f). Sample (b) annealed with thermal oxide, all other samples annealed with the TEOS cap.

(d)



(e)

(f)

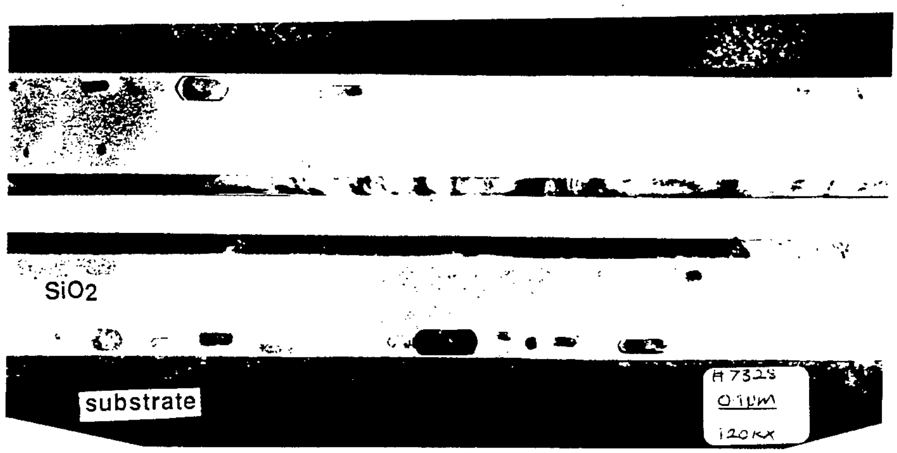


Figure 2 (continued). TEM cross section of samples implanted at 65 keV with the doses $1.5x10^{17}O^{+}/cm^{2}$ (a), $2.0x10^{17}O^{+}/cm^{2}$ (b), $3.5x10^{17}O^{+}/cm^{2}$ (c), $4.0x10^{17}O^{+}/cm^{2}$ (d) and $4.5x10^{17}O^{+}/cm^{2}$(e) and $7.0x10^{17}O^{+}/cm^{2}$ (f). Sample (b) annealed with thermal oxide, all other samples annealed with the TEOS cap.

The structural characteristics of the BOX and the silicon layer were further examined with the RBS technique. Samples implanted with the doses $2.0x10^{17}O^+/cm^2$ and $2.5x10^{17}O^+/cm^2$ at 65 keV and annealed at 1350°C with thermal or TEOS caps were compared to the control sample implanted with the dose $4.1x10^{17}O^+/cm^2$ at 200 keV and annealed with thermal oxide on the surface. Data analysis has shown the stoichiometric buried oxide in sample implanted with the $2.0x10^{17}O^+/cm^2$ at 65 keV and annealed with thermal oxide on the surface. The buried oxide of the control sample ($4.1x10^{17}O^+/cm^2$, 200 keV) was found to be silicon rich. The ratio of oxygen to silicon in 200 keV sample was 1.85 compared to 2.03 in the best samples from the 65 keV matrix.

The crystalline quality of the silicon layer of the 65 keV samples annealed with thermal oxide was comparable to the crystalline quality of the control wafer and the virgin silicon wafer (X_{min} = 4 - 6 % in samples implanted with the doses $2.0x10^{17}O^+/cm^2$ and $2.5x10^{17}O^+/cm^2$ at 65 keV, and $4.1x10^{17}O^+/cm^2$ at 200 keV, X_{min} = 3.5 (+/- 0.5)% in virgin silicon sample). The value X_{min} = 70% in samples annealed with the TEOS cap implies that the TEOS process needs more development. The representative RBS data of the 65 keV sample and the control sample is shown in Figure 3.

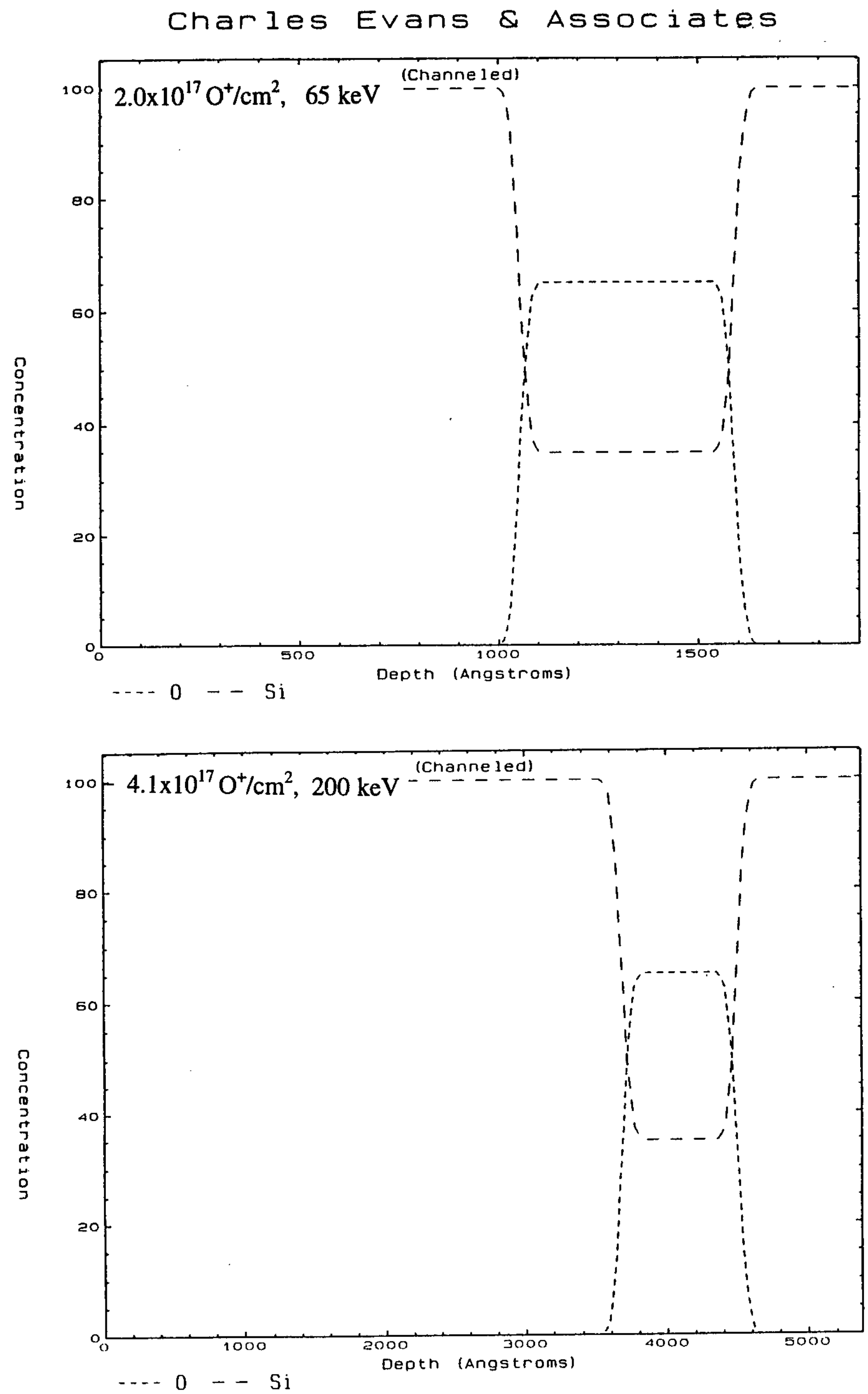


Figure 3. The channeled RBS spectra of the sample implanted with $2.0 \times 10^{17} O^+/cm^2$ at 65 keV and the control sample implanted with $4.1 \times 10^{17} O^+/cm^2$ at 200 keV.

Contamination in as-implanted wafers was measured with the TXRF. The total concentration level was below $10^{11}/cm^2$, meeting the typical criteria of standard SIMOX process. The representative TXRF spectra of the as-implanted sample is shown in the Appendix 1.

Impurity concentration profiles of the transition metals in the annealed wafers measured with SIMS are shown in Figure 4. The residual concentrations of 10^{15} - 10^{16} at/cm^3 of Cu, Ni, and Cr are observed in the silicon layer, while iron is at the detection limit. These impurity levels can be further reduced by process optimization.

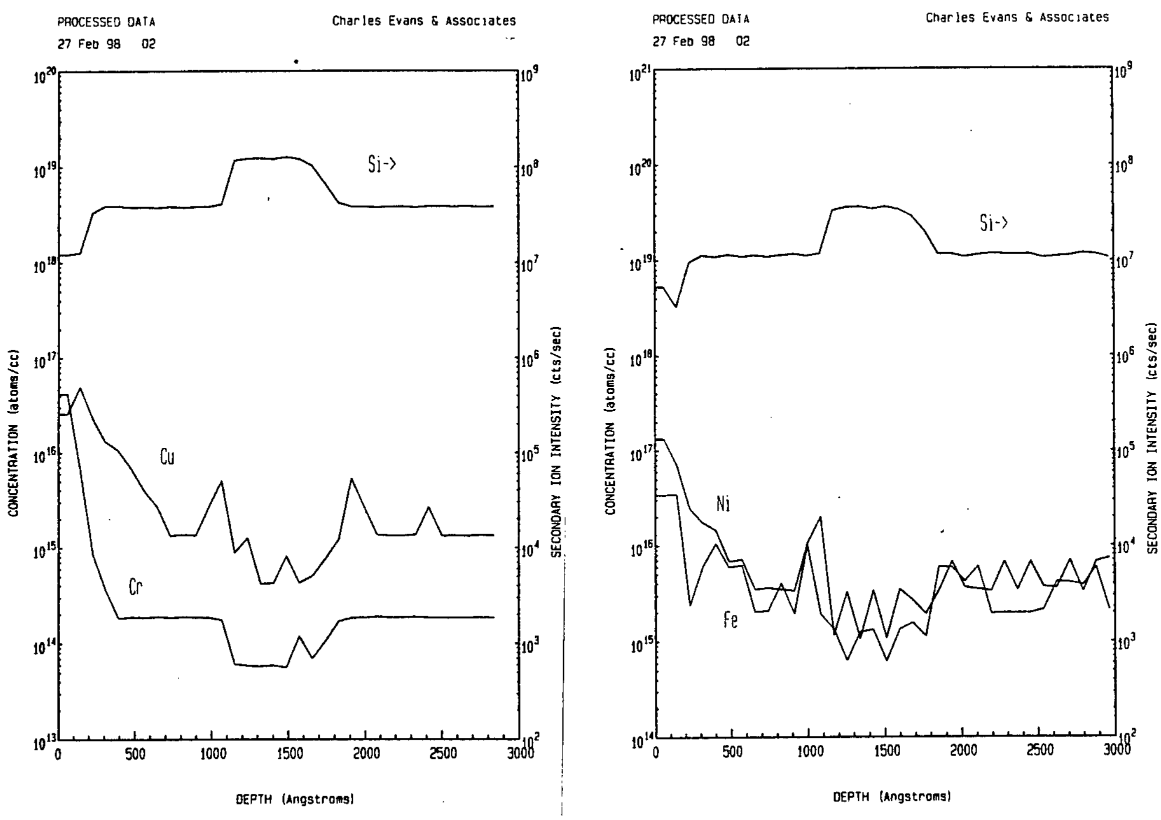


Figure 4. Impurity concentration profiles of the sample implanted with $2.0x10^{17}O^+/cm^2$ at 65 keV and annealed for 4 hours at 1350 °C in Ar(<1%O_2).

2.3.2 Silicon defect density.

The crystalline quality of the top silicon layer was examined utilizing the chemical analysis method. To determine the silicon defect density diluted enhanced Secco etch technique was followed by microscopic observations was utlilzed[17]. The dependence of the silicon defect density on the dose implanted at 65 keV is shown in Figure 5. Samples with continuous buried oxide exhibited silicon defect density of 1.95×10^5 /cm^2. This result was obtained in the implantation process at temperature 500 °C, achieved in the present implanter set-up at 65 keV. However, it is believed that in the optimized low energy process, higher wafer temperatures can be reached during the implantation and the resultant defect density will be reduced. The defect density in the 2×10^5 O^+/cm^2 65 keV sample was 2 orders of magnitude lower than in the control sample implanted at 200 keV.

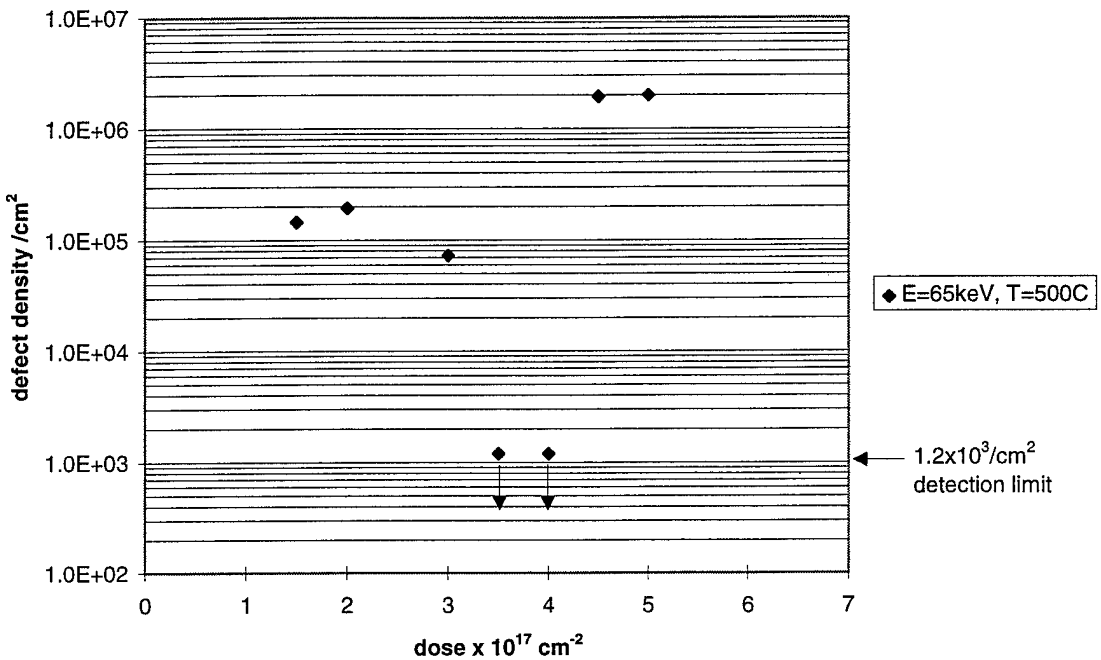


Figure 5. Silicon defect density in SIMOX implanted at 65 keV.

2.3.3 Surface and Interface Morphology.

The AFM analysis of samples implanted at 65 keV has shown very smooth silicon surface in all samples. Presence of the capping layer during the anneal slightly altered the short range topography but did not have noticeable effects on the calculated microroughnes parameters. The RMS was in the range of 0.11 to 0.17 nm in samples implanted with the doses from the low end and also from the high end of the examined dose range. These RMS values are at least 2 times lower than in the high energy SIMOX

annealed in inert ambient, and comparable to ITOX[18]. Examples of surface and interface topography are shown in Figures 6 -8. Figure 6 shows the 2.0 x 2.0 um AFM image of the top silicon surface of the sample having 110 nm thick silicon layer (sample implanted with $2.0x10^{17}O^{+}/cm^{2}$ annealed with thermal oxide) and Figure 7 shows the surface of the sample with 33 nm thick top silicon layer (the $7.0x10^{17}O^{+}/cm^{2}$ sample annealed with the TEOS cap). These are the very similar results for the two extreme process conditions examined in this experiment.

Microroughness of the silicon/buried oxide interface was in the range of 0.4 - 1.05 nm for samples implanted with the doses $2.0x10^{17}O^{+}/cm^{2}$ and $7.0x10^{17}O^{+}/cm^{2}$ respectively, which is also in the range comparable to the ITOX samples[19]. The AFM image of the top interface of the lower dose sample with high quality BOX is shown in Figure 8.

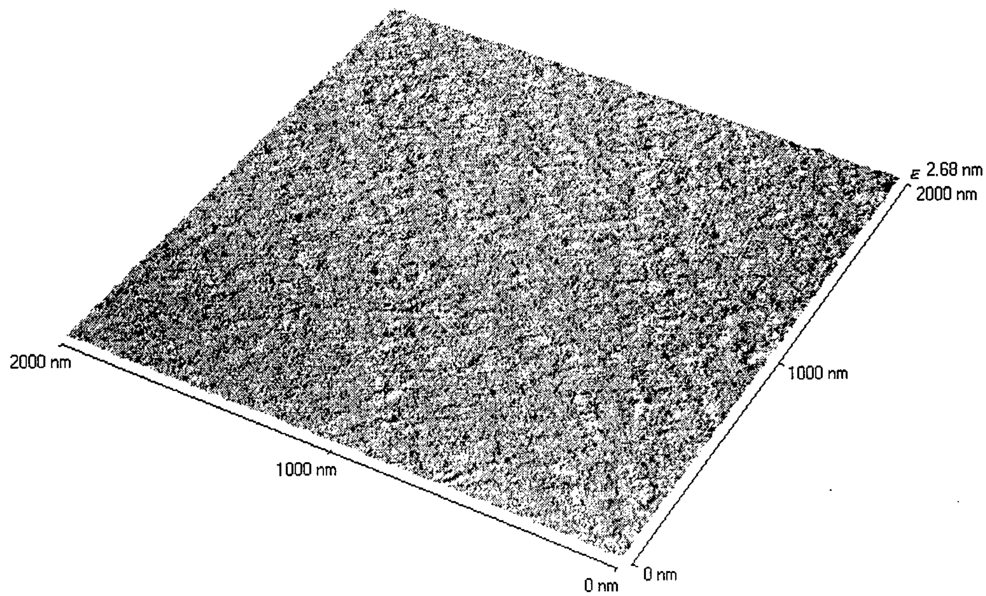


Figure 6. AFM images of the samples implanted with $2.0x10^{17}O^{+}/cm^{2}$ at 65 keV and annealed at 1350 °C for 4 hours in Ar(<1%O_2). Ra=0.135 nm, RMS=0.173 nm.

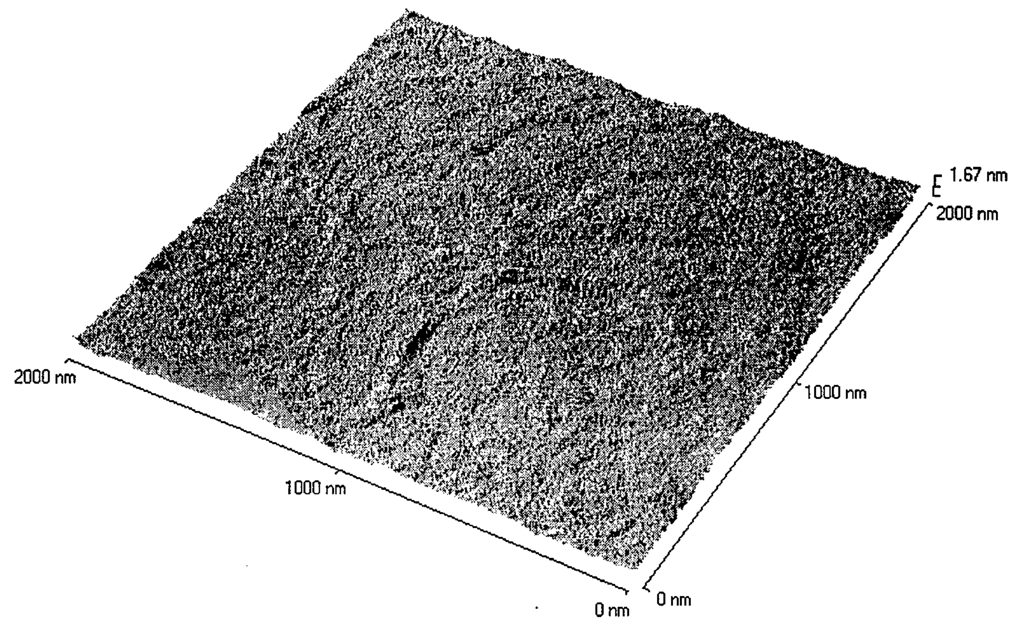


Figure 7. AFM images of the samples implanted with $7.0x10^{17}O^{+}/cm^{2}$ at 65 keV and annealed with the TEOS cap at 1350 °C for 6 hours in $Ar(5\%O_2)$. Ra=0.085 nm, RMS=0.112 nm.

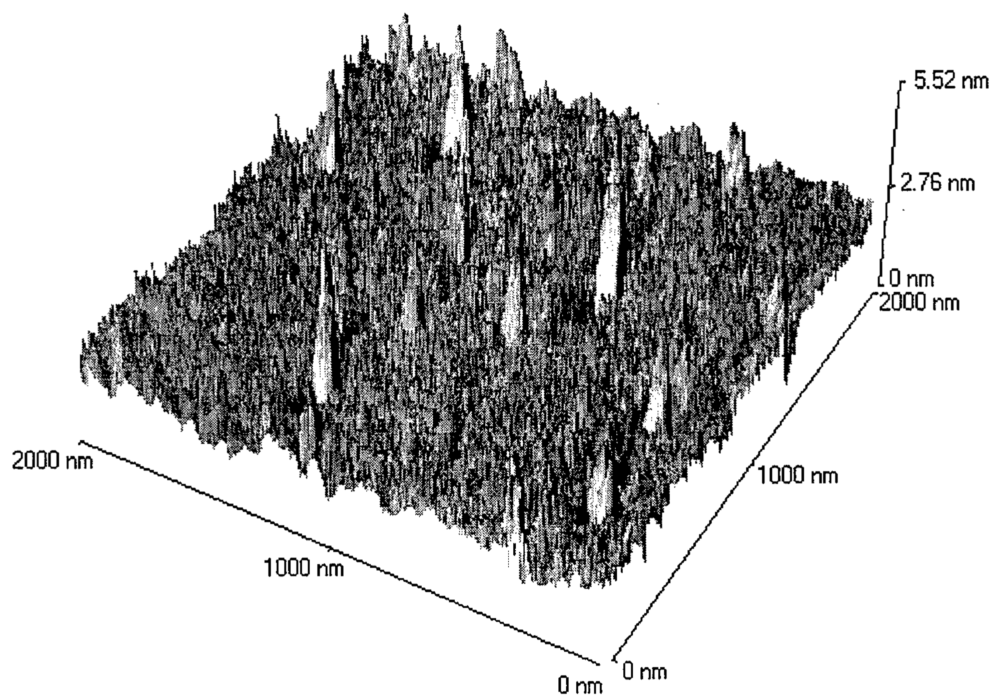


Figure 8. AFM images of the top interface of the sample implanted with $2.0x10^{17}O^{+}/cm^{2}$ at 65 keV and annealed at 1350 °C for 4 hours in $Ar(<1\%O_2)$. Ra=0.311 nm, RMS=0.423 nm.

2.3.4 Electrical Characteristics.

Electrical characterization of samples exhibiting best structural characteristics (dose $2x10^5$ O^+/cm^2) was performed at NRL. Capacitor structures were fabricated on the surface of the BOX by evaporation of aluminum and selective etching. The capacitors built in the sample annealed with the TEOS cap were shorted, since their BOX had silicon bridges. However, several devices with high integrity buried oxide with the intrinsic breakdown field of 4-6 MV/cm were found in the sample annealed with thermal oxide. This result is comparable to the superior values in commercial SIMOX. The yield on the measured samples was ~30% and should be increased with process improvement and optimization. The I-V characteristic of the 65 keV sample implanted with the dose $2x10^5$ O^+/cm^2 and annealed at 1350°C in Ar (<1%O_2) is shown in Figure 9.

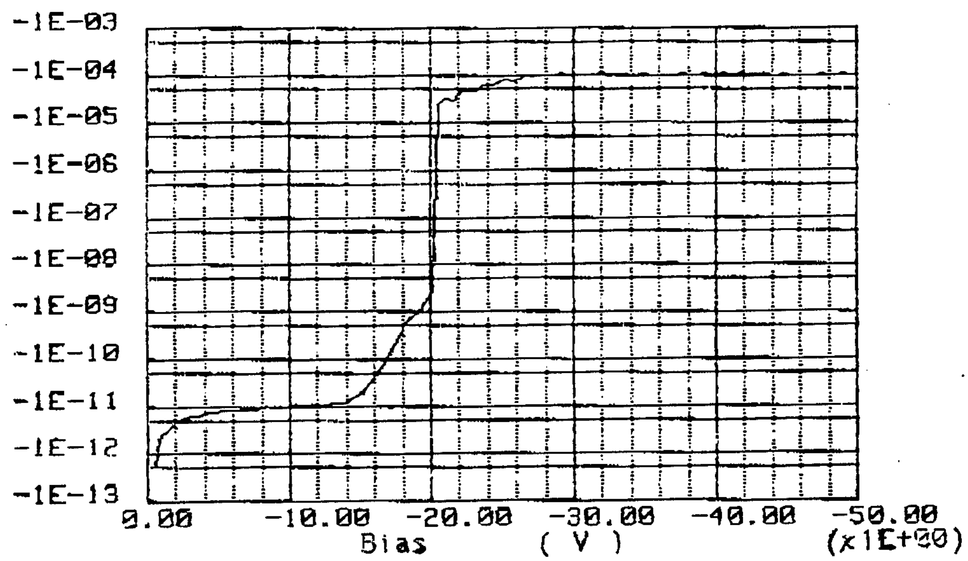


Figure 9. I-V characteristic of the SIMOX sample implanted with $2x10^5O^+/cm^2$ at 65keV and annealed at 1350°C in Ar (<1%O_2). BOX thickness 50 nm.

2.3.5 Summary and Conclusions.

The work performed in Phase I of this program aimed at the demonstration of the reduced energy implantation in high beam current implanter Ibis1000 and analysis of basic material characteristics of the low-energy SIMOX. The examined dose range covered the entire range of SIMOX formation at 65 keV. The dose of $2x10^5$ O^+/cm^2 was

found to be within the low dose process window at 65 keV. The dose of $7x10^5$ O^+/cm^2 was found to be near the range corresponding to the full dose high-energy SIMOX.

The diluted enhanced Secco etch revealed the defect density of $1.95x10^5$ $/cm^2$ in the $2x10^5$ O^+/cm^2 sample, which is lower value than observed in the control high energy SIMOX sample ($\sim 10^7$ $/cm^2$). High intrinsic breakdown field measured in the low dose 65 keV sample indicates that the 50 nm thin buried oxide formed at reduced energy can achieve the dielectric strength comparable to the high energy SIMOX while simultaneously demonstrating lower silicon defect density. Microroughness of the top silicon surface and silicon/buried oxide interface were found to be comparable to the best results achieved in current commercial ITOX processes. The above data was achieved in non-optimized conditions, and further defect density reduction is highly possible with optimized implantation and annealing processes.

Encouraging results of our Phase I work, demonstration of the process in Ibis 1000 implanter, promising and competitive material characteristics clearly show the feasibility of the low-dose low-energy SIMOX. Larger experimental data base, detailed characterization with the advanced methods, and more fundamental research in formation of the material are required to advance this development into the product. Development of this process scale-up-to-production requires a substantial effort in this very new approach in high current implantation. These efforts may be significantly advanced by a support of the Phase II research program.

3.0 REVIEW OF THE TASK STRUCTURE

3.1 TASK 1.

Obtain single crystal, <100> oriented, 10-20 Ohmcm, and also >100 Ohmcm, p-type, 150 mm silicon wafers.

This task was performed as described in section 2.1.

3.2 TASK 2.

Perform matrix of low dose implant processes at energy lower than 100 keV (65 keV).

This task was performed as described in section 2.1.

3.3 TASK 3.

Perform the annealing processes designed for very thin film layer structure.

This task was performed as described in section 2.1.

3.4 TASK 4.

Fabricate the 150 mm diameter control group wafers following the DARPA DOE 2.6 recipe.

This task was performed as described in section 2.1.

3.5 TASK 5.

Perform structural and electrical characterization of the experimental wafers and control wafers.

This task was performed as described in section 2.2.

3.6 TASK 6.

Evaluate effects of the process conditions on low dose energy SIMOX.

This task was performed as described in section 2.2.

3.7 TASK 7.

Analyze feasibility of low dose energy SIMOX and its potential for further developments.

This task was performed as described in section 2.3.5

4.0 RECOMMENDATION FOR THE PHASE II WORK.

The results of the Phase I program have shown high potential of the reduced energy SIMOX from the point of view of the material quality and process manufacturability. In spite of the above very encouraging results, it is proposed to continue the investigations and optimization of SIMOX implanted at 65 keV. Proceeding with the Phase II program would allow to better understand the formation mechanisms and resultant characteristics of this material and would advance its practical implementation.

The following milestones are recommended for the Phase II investigations.

- Equipment optimization to assure high beam current and implant uniformity.
- Investigations of implant conditions for the formation of high quality silicon layer and high integrity buried oxide at 65 keV in a reproducible manner, determine the process window.
- Investigation of the effect of the annealing scheme on the material characteristics of the low-dose low-energy SIMOX.
- Optimization of implant and anneal conditions for ultra-thin film SIMOX structure.

Completion of the above proposed program would result in the development of the new generation of ultra-thin layer SIMOX. In addition to the material quality suitable for fully-depleted devices with the minimum feature size below 0.18 um, the low dose process optimized for the high beam current implanter would offer significant cost advantages. The cost of the SIMOX wafer could be lowered by the formation of SIMOX with lower oxygen doses at lower energy, and even further reduced by the reduction of the cost of the implanter manufacture utilizing this approach.

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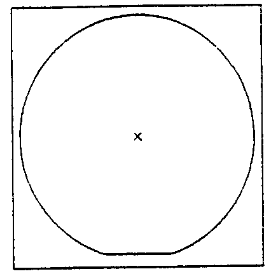
Appendix 1.



Date: 01/30/98 10:58:53

Sample: QC
Memo1:
Memo2:

Operator:

File: 9613

Sub.: Si WAFER

M. Spot
X: 0.06 mm
Y: 0.10 mm
Angle: 0.100 deg

X-ray
Voltage: 25 KV
Current: 150 mA
TARGET: W

Size: 6 inch
Slot: 2
Time: 500 sec
D.T.: 0.60 %

Element Cond.: ELEMENTS
Quant. Cond.: QUANT
D.P. Cond.: 1PT6

Spectrum	Energy keV	Peak Int.cps	Conc. *E10	BG.Int. cps	Stand.Dev. cps
W -Lb1	9.67	136.8460			
Ti-Ka	4.51	0.0000	0.00	0.0543	0.010
Cr-Ka	5.41	0.0000	0.00	0.0394	0.009
Fe-Ka	6.40	0.0327	3.74	0.0346	0.012
Co-Ka	6.93	0.0000	0.00	0.0309	0.008
Ni-Ka	7.47	0.0229	1.75	0.1004	0.016
Cu-Ka	8.04	0.0000	0.00	0.0880	0.013
Zn-Ka	8.63	0.0000	0.00	0.2523	0.022